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# BULLETIN

OF THE

## AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

## MONTREAL MEETING

AT

MONTREAL, CANADA

June 19–20–21, 1947

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# The American Physical Society

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# BULLETIN

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AMERICAN PHYSICAL SOCIETY

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JUNE 19, 1947 Vol. 22, No. 3

# BULLETIN

OF THE

# AMERICAN PHYSICAL SOCIETY

MONTREAL MEETING, JUNE 19–20–21, 1947

THE **279th meeting of the American Physical Society** will be held at Montreal on Thursday, Friday, and Saturday, June 19, 20, and 21, 1947. This will be our first meeting at Montreal since 1926, and our first in Canada for almost as long a time. We owe this welcome opportunity to an invitation from the Principal of McGill University, Dr. F. Cyril James. Our sessions will be held in the MacDonald Physical Laboratory of this University and in the Arts Building containing the Moyse Lecture Theatre. The University campus lies north of Sherbrooke street, three blocks east of Peel street in which are located the Windsor and the Mount Royal hotels.

The **physics of the solid state** is the theme of a Symposium to be held on Saturday morning and afternoon, organized by the Committee on Solid-State Physics which is initiating a Division of the Society. It is also the theme of a large percentage of our seventy-two contributed papers, another large percentage of these pertaining to nuclear physics. The contributed papers are distributed in seven sessions, two on Thursday afternoon and one on each of the other five half-days of the meeting.

Our Canadian colleagues F. J. Belinfante, H. Carmichael, M. F. Crawford, J. S. Foster, G. Placzek, A. G. Ward, and H. L. Welsh will present **invited papers** on a diversity of subjects on Friday morning and afternoon.

The **registration desk** will be located in the Arts Building. All members and guests are asked to register so that we may have accurate statistics of attendance, and to call at the desk occasionally for messages and mail.

The **dinner** of the Society, planned for Thursday evening, was cancelled for want of advance reservations: but we have arranged a dinner for Friday evening at seven in the Hotel Windsor. Tickets should be purchased at the registration desk before noon on Thursday: members who cannot arrive before noon are entreated to send checks ($3.30 per place, tax and tips included) to Professor A. Norman Shaw at McGill University, Montreal, before the meeting.

**Hotel reservations must be sought IMMEDIATELY** (!!) from the Windsor, Montreal and Queen's Hotels, preferably by telegraph. (**Mention The American Physical Society in your telegram or letter.**) The deadline will be very close when this Bulletin reaches our members.

A **garden-party** is being graciously offered by McGill University for Thursday afternoon from four to six. Posters at the registration desk will inform our members and guests of the location.

The **Council** will meet in the Faculty Room in the Arts Building, Friday afternoon at half-past four.

**Prospective meetings.** Meetings of the American Physical Society are scheduled to be held as follows: Stanford University, California, July 11–12; Houston, Texas, November 28–29; Chicago, Illinois, December 29–31; 1947 Annual Meeting to be held in New York City, January, 1948 (probably January 29–31).



JUN 10 1947

### General Rules Relating to Papers

**The By-Laws of the Society stipulate that no paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for the meeting.**

**The time allowed for the oral presentation of a contributed paper is ten minutes at most.**

**When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this** programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review.*

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

# PROGRAMME

THURSDAY MORNING AT 10:00

Moyse Lecture Theatre

(G. B. PEGRAM presiding)

**Address of Welcome.** F. CYRIL JAMES, *Principal, McGill University*

(G. F. HULL, JR. presiding)

***Contributed Papers***

## *Cosmic Rays and Nuclear Physics*

**A1. "Fragmentation" Bursts at Sea Level.** H. CARMICHAEL, *National Research Council of Canada, Chalk River, Ontario.*—Recordings of cosmic-ray ionization made at Cambridge, England, prior to 1936 in a large (175 liter) ion-chamber filled with A, $N_2$ and $H_2$, at pressures not much above atmospheric, showed a very sudden large increase in the rate of occurrence of bursts smaller than about $10^6$ ion-pairs. It was shown at that time that these small bursts were produced by particles of range short compared with the size of the ion-chamber and they were ascribed to contamination alpha-particles (i.e., 8, 7, 6, etc., particles occurring within a time interval of 0.5 second). This explanation of these bursts never appeared to be completely satisfactory but confirmation of their cosmic-ray origin was not forthcoming until they were compared with the recent data of Kingshill and Lewis. It is now evident that these bursts must be caused mainly by heavily ionizing nuclear fragments of local origin (variously called vaporizations, explosions, or stars). These small bursts are not to be confused with the steeper branches of curves published in 1939 which are known to be due to showers of thinly ionizing particles. Measurements of the original recordings have now been extended to much smaller burst sizes and an attempt is made to correlate all the measurements of both types of bursts with the results of other authors.

**A2. Further Investigation of Frequency of Occurrence of Small Cosmic-Ray Bursts.** JAMES W. BROXON, *University of Colorado.*—Using Chree's method of superposed epochs, the writer[1] recently found secondary pulses in the frequency of small bursts in a heavily shielded chamber occurring about 27 days before and after primary pulses. As in the case of average ionization currents,[2] the analysis has been extended to investigate correlation with other variables. The method does not indicate clearly a dependence of burst frequency upon magnetic character, nor even a very close relation to the mean ionization current. It does strongly indicate a relation to sunspot areas; fairly regular pulses extending to nearly 10 percent of the mean frequency of the small bursts occur in approximate phase opposition to the primary pulses in sunspot area.

[1] J. W. Broxon, Phys. Rev. **70**, 494 (1946).
[2] J. W. Broxon, Phys. Rev. **62**, 508 (1942).

**A3. Cosmic-Ray Induced Fission.** DAROL FROMAN, LOUIS ROSEN, AND BRUNO ROSSI, *Los Alamos.**—Eastman special fission plates in contact with 1 mg/cm² metallic foils of U-235 (bare and surrounded with 2″ of paraffin), U-238, Pb, and Bi were exposed to cosmic-ray neutrons during five-hour flights at 25,000 and 30,000 ft. The plates are insensitive to alpha and other radiations but record all fission-fragment tracks. At the time of writing this abstract, examination of the plates is incomplete. However, the following results are clear already. The flux of neutrons of energy above the fission threshold of U-238 is small since no tracks have been found in 0.4 cm² of plate examined to date. Cursory examination has given no indication of fission in Pb or Bi. The fission rates of the bare and paraffin-covered U-235 foils are about those which would result on exposure of the bare foils to thermal neutron flexes of 20 and 130 neutrons/cm² min, respectively, calculated on the basis that the thermal fission cross section for natural uranium is 3 barns. The precision of these values is low but will be improved greatly on further examination of the plates before the meeting.

* Based on work done under contract with the Atomic Energy Commission. The last-named author is now at M.I.T.

**A4. Delayed Neutrons from $Pu^{239}$.** F. DE HOFFMAN AND B. T. FELD,* *Los Alamos.*—The delayed neutrons emitted from $Pu^{239}$ have been investigated both with regard to the fraction of all neutrons emitted as delayed neutrons and the delay periods.[1] The ratio of the relative number of delayed neutrons in $Pu^{239}$ to that in $U^{235}$ was found to be 0.47 for neutrons delayed over 2 seconds and 0.40 for neutrons delayed over 5 seconds. Because of the experimental uncertainties these two numbers are probably not significantly different. The shape of the delay curve is found to be very closely the same as that of $U^{235}$.[2] The delayed neutron decay curve for long irradiation can be represented by the following expression:

$$I=0.301e^{-t/1.6}+0.371e^{-t/7.5}+0.288e^{-t/32.5}+0.040e^{-t/79.6}$$

where $t$ is in seconds and $I(t=0)$ is arbitrarily taken equal to one. This work was carried out under contract with the War Department.

* Now at Massachusetts Institute of Technology.
[1] This work was completed February 1945. Previous work was done by R. R. Wilson, Phys. Rev. and C. Redman and D. Saxon (to be published).
[2] See, for instance, A. H. Snell, Phys. Rev. **70**, 111 (1946).

**A5. On the Asymptotic Distribution of Diffusing Monoenergetic Neutrons.** P. R. WALLACE,* *National Research Council of Canada, Chalk River.*—It is shown that, in general, the neutron distribution in a finite homogeneous medium $R$ may be treated as due to appropriately chosen sources in an *infinite* homogeneous medium, these sources being distributed over the region *outside* $R$. Such considera-

tions lead in general to an integral equation for the distribution rather different from the usual Wiener-Hopf integro-differential equation. In particular, this method enables one to obtain perfectly general relations between the angular moments of the asymptotic distribution, independently of the nature of the artificial "sources" referred to above. Thus, for instance, the relation expressing the proportionality of current and gradient of density in the asymptotic region is obtained quite generally and rigorously, without any assumptions about the relative magnitudes of capture and scattering cross sections. The higher moments of the angular distribution are obtained similarly in terms of the higher derivatives of the density. These considerations have been applied, by way of illustration, to obtain information about the angular distribution in a number of simple cases.

* Now at McGill University.

**A6. Fluctuations of Neutron Intensity in a Chain-Reacting Pile.** E. D. COURANT* AND P. R. WALLACE,** *National Research Council of Canada, Chalk River.*—The method of probability generating functions has been used to study the fluctuations of integrated neutron intensity in chain-reacting piles. A general partial differential equation is obtained for this function, from which are obtained equations for the moments (the first moments are mean values of intensities of neutrons and of neutron-emitting excited fission product nuclei; the second moments are related to their mean-square fluctuations and correlations). The case of a steady power level (constant mean values) has been considered in detail. It is found that the fluctuations do not in general go as $N^{\frac{1}{2}}$ ($N$ being the integrated neutron intensity), but for moderate or high power vary directly with $N$; in other words the *relative* mean square fluctuations approach a constant magnitude. This fact is related to the wide range of variation in the lengths of the multiplication chains initiated by the production of a neutron. The frequency spectrum of the fluctuations has been determined, and it has been used to study the effect on *observed* fluctuations of the resolving time of the measuring instrument and of the finite time of observation.

* Now at Cornell University, Ithaca, New York.
** Now at McGill University, Montreal, Canada.

**A7. The Polarization of the Neutron in an Electrostatic Field.** K. M. WATSON, *Iowa State University.*—According to the meson theory of nuclear forces, there is a meson charge cloud enveloping a neutron (or proton). An external electric field will polarize this cloud, causing the neutron to have an electric dipole moment. The results for scalar, pseudoscalar, and vector mesons are the same except for numerical factors. The neutron dipole moment in a field $E$ is approximately (here $\hbar=c=1$)

$$\alpha \simeq 0.1 \frac{\epsilon^2 g^2}{\mu^3} E$$

where $\epsilon$, $g$, and $\mu$ are the electronic charge, dimensionless coupling constant, and meson rest-mass. This will give rise to an elastic scattering cross section for $\gamma$-rays scattered by neutrons and to an electrostatic attraction between neutrons and protons or electrons.

**A8. The Radial Dependence of the Tensor Force in the Deuteron.** WILLIAM G. GUINDON, S. J., *Massachusetts Institute of Technology.*—The deuteron ground-state equations are solved using an $n-p$ interaction: $V=-[J_1(r)+\gamma S_{12}J_2(r)]$. In contrast to previous work,[1] first, the small spin-exchange interaction has been omitted and, second, in the square-well model employed the ranges of ordinary and tensor forces may be different. In place of a single well of depth $V_0$ and radius $r_0$, two wells of common depth $V_0$ (determined from the $n-p$ singlet scattering cross section) and radii $r_0$ and $\epsilon r_0$ represent $J_1(r)$ and $J_2(r)$ respectively. For a given choice of $r_0$ and $\epsilon$, the potential $V_0$ and the binding energy $E_0$ determine $\gamma$ and the quadrupole moment $Q$. By appropriate choice of $\epsilon$, $Q$ may be made equal to the experimental value, for any $r_0$. For radii in the range $r_0=(2.8\pm0.2)\times10^{-13}$ cm, preliminary results indicate that (1), the correct ratio covers the range $\epsilon=0.95\mp0.10$, and (2), the $D$-state probability at all these ranges is constant at 4.4 percent. Hence, in this model, (1) the quadrupole moment is rather sensitive to the ratio of the ranges, and (2) no preferred radius $r_0$ is indicated by comparison of the $D$-state probabilities with experimental magnetic moments.

[1] W. Rarita and J. Schwinger, Phys. Rev. **59**, 436 (1941).

**A9. The Range of Nuclear Forces.** H. C. CORBEN AND MULAIKA CORBEN, *Carnegie Institute of Technology.*—Experimentally it has not yet been established that the ranges $r_{np}$ and $r_{pp}$ of neutron-proton and proton-proton forces are identical. On the assumption that charged and neutral mesons possess different masses $\mu_c$, $\mu_n$ but the same coupling constant with nucleons, we therefore investigated the pseudoscalar and vector meson theories of nuclear forces in the weak coupling approximation. The potential energies $V_{pp}{}^{1S}$, $V_{np}{}^{1S}$ and (apart from the tensor force) $V_{np}{}^{3S}$ of a two nucleon system then exhibit different $r$-dependence, but as they may be replaced approximately by square wells of identical "volume" $V_0a^2$ the corresponding energy levels are practically independent of the ratio $\mu_c/\mu_n$. The range $r_{np}$ is then determined by the smaller of $\mu_c$, $\mu_n$ so that $r_{pp}\leq r_{np}$ and $\mu_c\geq\hbar(cr_{np})^{-1}$. Violation of the first of these conditions would be difficult to understand on any theory; violation of the second would be a sufficient, though not necessary, condition for eliminating the symmetrical meson theory.

**A10. The High Energy Limit of the $C^{14}$ Beta-Ray Spectrum.** W. E. STEPHENS AND MARGARET N. LEWIS, *University of Pennsylvania.*—The beta-ray spectrum of $C^{14}$ is being investigated by means of a permanent magnet spectrograph.[1] The preliminary value of the apparent end point is $0.15\pm0.02$ Mev, which agrees with Ruben and Kamen's[2] value of 0.145 Mev. Further efforts to reduce scattering and increase the $C^{14}$ density in the surface of the source are being made.

[1] E. H. Plesset, G. P. Harnwell, and F. G. P. Seidl, Rev. Sci. Inst. **13**, 351 (1942).
[2] Ruben and Kamen, Phys. Rev. **59**, 349 (1941).

**A11. The 40-kev transition of ThC″.** B. B. KINSEY, *National Research Council of Canada, Chalk River.*—It is well known that the disintegration of ThC with the emission of $\alpha$-particles gives rise to an excited state of ThC″ at 40 kev. In 1934, Lewis and Bowden, in studying the fine structure of these particles, found that the state is excited in 70 percent of the disintegrations. This transition is of some interest in that the number of conversion electrons due to it is known to be less than one half of the number of excited states which are formed, while the $\gamma$-radiation has so far eluded detection. Noting an observation due to Ellis which indicates that the lifetime of the state is less than $10^{-8}$ sec., an attempt has been made to detect this radiation by a coincidence method using a counter with a xenon filling. A small effect was obtained amounting to about 4 quanta per 100 disintegrations. The emission of $\gamma$- and $L$-radiation is now being studied intensively by absorption and by diffraction methods.

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## THURSDAY AFTERNOON AT 2:15

MacDonald Physics Laboratory, Room 102

(D. A. KEYS presiding)

### *Nuclear Physics and Electrical Apparatus*

**C1. The Decay Scheme of $Sc^{46}$.** ARTHUR E. MILLER AND MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—$Sc^{46}$ produced by slow neutron exposure of scandium in the Clinton pile is shown to emit negative beta-particles of maximum energy $0.36\pm0.01$ Mev. Each beta-particle is followed by the emission of two gamma-rays of $1.12\pm0.02$ Mev and $0.90\pm0.02$ Mev energy, making the disintegration energy $2.38\pm0.03$ Mev. Absorption measurements using a window-less counter gave identical results for He and A filling of the counter indicating the absence of $K$ capture. This work was supported in part under contract N5ori-78 with the Office of Naval Research.

**C2. The Decay of $Ag^{110}$ (200 Day).** MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—$Ag^{110}$ produced by slow neutron exposure of silver in the Clinton pile emits no detectable $K$ x-rays. $K$-electron capture cannot constitute more than three percent of the disintegrations. The beta-ray spectrum is complex. More than half of the beta-particles are absorbed by 2 mg/cm² of aluminum. This explains the large ratio of gamma-ray to beta-ray count obtained with the usual counters. The $\gamma$-ray spectrum is more complex than previously reported.[1] The 0.9-Mev line[1] is resolved into two components separated by about 0.06 Mev. There is some evidence that the 1.5-Mev line[1] also is complex. This work was supported in part under contract N5ori-78 with the Office of Naval Research.

[1] Deutsch, Roberts and Elliott, Phys. Rev. **61**, 389(A) (1942). Rall and Wilkinson, Phys. Rev. **71**, 321(L) (1947).

**C3. The Indium Isotopes Produced by Bombardment of Silver with 20-Mev Alpha-Particles.*** D. J. TENDAM AND H. L. BRADT, *Purdue University.*—The assignments of mass numbers 110 and 112, respectively, to the 66-minute and 23-minute In activities are confirmed by their practically identical excitation curves which show clearly that these activities are produced by $Ag(\alpha, n)$ reactions. The decay scheme of the 23-minute $In^{112}$ will be discussed. Whereas the excitation curves for these short periods are almost flat at 20 Mev, that for the 2.7-day In activity still rises steeply. This 2.7-day activity, also produced by $Cd(d, n)$ and $Cd(p, n)$ reactions, obviously is the result of a $Ag(\alpha, 2n)$ reaction, the threshold being $(15\pm0.5)$ Mev. The 2.7-day period hence must definitely be assigned to mass number 111. We have produced by $\alpha$-bombardment of Ag a new 6.5-hour In activity which decays chiefly by $K$-capture to an excited state of the product Cd nucleus, only a few percent of the decay processes leading to the ground state by emission of a forbidden 2-Mev positron spectrum. Because of the shape of its excitation curve, with a threshold ~13 Mev, the 6.5-hour activity is tentatively assigned to $In^{109}$, as the product of the $(\alpha, 2n)$ reaction with $Ag^{107}$. However, we have thus far been unable to detect the 330-day $Cd^{109}$ activity which should grow out of $In^{109}$.

* Assisted by the Office of Naval Research.

**C4. The Relative Yields of $(\alpha, n)$ and $(\alpha, 2n)$ Reactions with 15–20 Mev Alpha-Particles.*** H. L. BRADT AND D. J. TENDAM, *Purdue University.*—Excitation curves for $(\alpha, n)$ and $(\alpha, 2n)$ reactions have been measured for several elements. As has been shown by R. N. Smith in this laboratory (thesis, unpublished), the relative yield of the $(\alpha, 2n)$ reaction is negligible with $\alpha$-energies below 15 Mev for a large number of elements investigated. The yield of the $(\alpha, 2n)$ reaction may even, in some of these cases, be quite small at higher energies: for $Co^{59}$ for example, where both reactions lead to definitely assigned periods—the $(\alpha, n)$ reaction to the 9.92 minute $Cu^{62}$ and the $(\alpha, 2n)$ to the 3.4 hour $Cu^{61}$—the ratio of the $(\alpha, 2n)/(\alpha, n)$ thick target yield, as measured by the saturation intensity ratio of the annihilation radiation of the product $\beta^+$-emitters, is only 2 percent at 19 Mev. For $Ag^{109}$, where the $(\alpha, 2n)$ reaction whose threshold is at 15 Mev (see previous note), leads to

the 2.7 day $In^{111}$, the $(\alpha, 2n)/(\alpha, n)$ thick target yield ratio at 20 Mev is much larger, the $(\alpha, 2n)$ and $(\alpha, n)$ cross sections being nearly equal for this $\alpha$-energy. If the 6.2-hr. In period is to be assigned to $In^{109}$, as seems probable, the latter result holds also for the other silver isotope $Ag^{107}$.

* Assisted by the Office of Naval Research.

**C5. A Radiofrequency Spectrometer for the Detection of Resonance Absorption by Nuclear Moments.**[1] R. V. POUND, *Harvard University.*—An apparatus for searching in frequency for nuclear moment absorption lines has been constructed. It uses an oscillator with a circuit for automatically maintaining a given low level of oscillation, while its frequency is slowly altered by a clock motor. The sample is placed in the oscillator tank coil and this is put in a modulated magnetic field. A phase mixer that measures the modulation-frequency component in the rectified oscillator voltage registers absorption lines on a recording milliammeter. The resulting apparatus is completely automatic and is of utility for searching for unknown gyromagnetic ratios and for investigating line shape. For these purposes a permanent magnet or an electromagnet regulated to maintain the proton line at a fixed frequency would be useful. Full advantage may thus be taken of the sensitivity of a device of small noise band width by using a sufficiently slow scanning rate. The recorded line is due only to absorption and is not influenced by dispersion. Measurements show it is possible to obtain a noise figure of less than 10, if the level of oscillation is kept low.

[1] E. M. Purcell, H. C. Torrey, and R. V. Pound, Phys. Rev. **69**, 37 (1946).

**C6. Design and Performance of Two of the Chalk River Ion-Chambers.** B. S. SMITH, H. CARMICHAEL, J. F. STELJES, C. O. PEABODY, AND D. S. CRAIG, *National Research Council of Canada, Chalk River.—Type TPA* is a cylindrical, gas-tight ion-chamber with a $\frac{1}{16}$ inch thick welded steel case, pressure tested to 30 atmospheres and having aluminum electrodes with quartz insulation. The collecting volume is 4.7 liters. Only metals and quartz are used in the construction and the chamber is usually baked out under vacuum before filling. The ion current in commercial argon at 20 atmospheres is 90 percent saturated at a voltage $V=10^6(I)^{\frac{1}{2}}$. In $BF_3$ at 20 cm Hg the current ($2.5\times10^{-13}$ amp for a flux of one slow neutron per sq. cm per second) is 90 percent saturated at a voltage $V=4.5\times10^5(I)^{\frac{1}{2}}$. *Type TQT* is a $3\frac{1}{2}$-inch diameter, gas-tight, aluminum ion-chamber, of similar construction, with one of its electrodes made of steel and coated with boron. The gas is argon at 50 cm Hg. This ion-chamber is for use in a high flux of slow neutrons and would be capable of passing a saturated ion current of one ma.

**C7. Some Characteristics of the Photo-multiplier Radiation Detector.** J. W. COLTMAN AND FITZ-HUGH MARSHALL, *Westinghouse Research Laboratories.*—A photo-multiplier tube with a fluorescent material can be used as a detector of single radiation quanta or particles provided that the initiating event releases a number of photoelectrons appreciably greater than the number of dark-current electrons emitted during the phosphorescent response time of the fluorescent material. With fast, efficient phosphors and with mirrors to gather the light, single pulses from x-ray quanta 25 kb and higher can be distinguished above background noise, as well as all types of ionizing nuclear radiations. 5-Mev alpha-particles have been observed to release about $10^4$ photoelectrons each and to give pulse heights 50 times background. 1.7-Mev beta-particles give pulse heights 10 times background. The pulse height is proportional to the energy released in the phosphor, and therefore roughly to the energy of the initiating event. For protons, alpha-particles, and beta-particles the counting efficiency approaches 100 percent; for high energy x-rays and gamma-rays, reduced absorption lowers the efficiency. A phosphor layer can be made with sufficient boron content to give a high efficiency for slow neutrons. The upper limit of the counting rate is set largely by the decay time of the phosphor, which is roughly $10^{-6}$ second.

**C8. The Photo-multiplier Radiation Detector.** FITZ-HUGH MARSHALL AND J. W. COLTMAN, *Westinghouse Research Laboratories.*—The photo-multiplier x-ray detector, consisting of a multiplier photo-tube to measure the light emitted by a fluorescent screen, has been extended in its use to the measurement of alpha-, beta-, and gamma-rays, high energy electrons and protons, and neutrons. Improved light-gathering methods and high frequency circuits have resulted in registration of individual quanta of all these radiations as pulses rising above the noise level of the photo-multiplier's input-stage dark current of $10^5$ electrons per second, permitting use of a discriminator-counter circuit. This removes the sensitivity limitation inherent when the instrument is used only for current measurement. At high intensities the detector can be switched from pulse counting to current measurement, with a wide range of overlap for calibration. Employing commercial photo-tubes and screens, this detector is simple, rugged, compact, and spectacularly fast. It competes favorably in sensitivity with all other detectors, including the Geiger counter, and it can cover a tremendous range of intensities. It is most suitable for use with narrow beams of radiation. Thin-window technique is unnecessary for beta-rays, since the phosphor is exposed. Dr. Kuan-Han Sun is responsible for extending the detector to neutron measurement, using boron impregnated phosphors to convert neutrons to alpha-particles.

**C9. A Speed Gauge for HV-Ion Beams.** WILLIAM ALTAR, M. GARBUNY, AND J. W. COLTMAN, *Westinghouse Research Laboratories.*—Increasingly accurate measurements of nuclear energy levels necessitate an accurate absolute voltage calibration. This is accomplished by a new method based on the original suggestions (R. O. Haxby, W. E. Shoupp, and W. E. Stephens) of timing transit of the beam between two r-f gaps, or transit through a resonant cavity. We obtain the required high accuracy (0.1 percent in voltage) and sensitivity (beam-current $10^{-6}$ A) by modulating the beam at the source with 70 mc, and after acceleration passing it through two accurately spaced gaps separated by a field-free drift space. The gaps

are tightly coupled through a high $Q$ cavity which resonates at the modulation frequency. Generally a particle contributes energy at each gap toward exciting the cavity mode. The resulting oscillation is fed to an indicator. Only when transit time between gaps is exactly an odd number (9) of half-cycles, will the two contributions from a particle cancel each other, giving null at the indicator. A cavity ($Q=6000$) has been built and tested, and should give adequate performance on the basis of computed signal and noise levels. Final runs will employ protons up to 4 Mev from the Westinghouse electrostatic generator.

**C10. The Maxwell Bridge at Low Frequencies.** V. A. BROWN AND B. P. RAMSAY, *Naval Ordnance Laboratory.*—The Maxwell bridge has been found useful for measuring inductance $L$ and a.c. resistance $R_{ac}$ at periods from 1 sec. to 200 sec. In some of the applications, the inductors had solid ferromagnetic cores and inductances of several hundred henries. The effect upon the bridge circuit of induced currents in the ferromagnetic material is expressed in terms of the equivalent mutual inductance $M$. The a.c. balance is imperfect unless $M$ is zero. Compensation for mutual inductance by means of an inverse network[1] of capacitors and resistors in the arm opposite $M$ is ineffective in the presence of ferromagnetic core material because the capacitors do not compensate for the effects of magnetic hysteresis. Hence the conventional Maxwell bridge has been selected; it yields approximate value of $L$ and $R_{ac}$. Factors determining the choice of bridge resistors and of balance indicator are discussed, and typical graphs of $L$ and $R_{ac}$ as functions of frequency are presented.

[1] A. T. Starr, Phil. Mag. **12**, 265 (1931).

**C11. The Fluxmeter in the Fluxbridge Circuit.** H. E. WOLF, H. E. CLEARMAN,[1] AND W. C. WINELAND, *Naval Ordnance Laboratory.*—The fluxbridge is a modification of the Rowland Ring Circuit in which a fluxmeter is used as a null indicator. The advantage of the fluxbridge for accurate work is that the fluxmeter, whether shunted or unshunted, is calibrated in the circuit in which it is used. The theory of the D'Arsonval galvanometer as a fluxmeter is examined, and the merits of using the fluxmeter as a null indicator are analyzed. The fluxbridge has been employed chiefly for measuring the detecting power of induction coils with ferromagnetic cores. Because transients in the fluxbridge have the effect of changing the state of magnetization of these cores, measurements of detecting power are reproducible only when transient currents are small. Resistance is used in series with the inductors to reduce the magnetizing effects of transients. In order to reduce the sensitivity of the fluxmeter, it is frequently desirable to operate it with a shunt. The time-constants and sensitivity of the fluxbridge are discussed.

[1] Now at Applied Physics Laboratory, Johns Hopkins University.

**C12. An Inductively Coupled Degenerative High Voltage Stabilizer.*** R. PEPINSKY AND P. JARMOTZ, *Alabama Polytechnic Institute.*—Conventional degenerative d.c. voltage stabilizers have a d.c. connection between the input error voltage and the series-tube grid circuit. This imposes inconvenient insulation problems for stabilized output voltages above a few kilovolts. To overcome these difficulties, a stabilizer has been constructed in which the series tube is inductively coupled to a feed-back amplifier, insulation between high and low voltage circuits having been provided in a transformer. The d.c. feed-back amplifier amplitude modulates a 2-megacycle oscillator. The resulting signal is transmitted through an r-f transformer with 150 kilovolts Bakelite insulation between windings. The output signal is rectified and filtered, and application of the resulting d.c. signal to the series-tube grid controls the voltage drop across that tube. The stabilizer has been used for voltages between 20 kv and 50 kv, at currents from 0 to 50 ma. It operates from a 60-cycle line. An input variation of 1500 volts at the series-tube plate causes an output fluctuation of one volt; a 3500-volt input variation causes a 3-volt output change. The output ripple at 30 kb and 20 ma is 0.05-volt r.m.s.

* Development supported by U. S. Army Signal Corps.

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## THURSDAY AFTERNOON AT 2:15

MacDonald Chemistry Laboratory, Main Lecture Theatre

(W. SHOCKLEY presiding)

### *Magnetic and Semi-Conducting Solids*

**E1. Directions of Magnetization in Powder Patterns.** H. J. WILLIAMS, *Bell Telephone Laboratories.*—Some of the simpler powder patterns previously observed[1] on single crystals of silicon iron have been interpreted, so that one knows the direction of magnetization in each portion of the surface. On surfaces almost parallel to (100) the numerous lines, inclined about 45° to a direction of easy magnetization, are boundaries between domains magnetized at 90° to each other. When the lines are just 45°, the normal component of magnetization is constant across the boundary, and there are no free poles; when they deviate from 45° some poles occur and are spread sparsely along the

lines. Such lines, slightly curved and joined to form spearheads, are observed when the plane of observation is slightly inclined to (100). They form domains of closure for the magnetization parallel to that direction of easy magnetization which intersects the surface at a small angle, and some flux escapes through the surface. They disappear when the surface is made accurately parallel to (100); the pattern then consists largely of lines parallel to one of the crystal axes, separating antiparallel domains.

[1] Phys. Rev. **70**, 106 (1946).

**E2. Ferromagnetic Resonance at Microwave Frequencies.** W. A. YAGER AND R. M. BOZORTH, *Bell Telephone Laboratories.*—Griffiths[1] has recently described a new resonance phenomenon in ferromagnetic materials at microwave frequencies, and Kittel[2] has given a theory which shows good agreement with the experiments already reported. Electrons having gyromagnetic ratio $\gamma$ are regarded as precessing about the applied field, $H$, at a microwave frequency given by $\omega=\gamma(BH)^{\frac{1}{2}}$ instead of the Larmor frequency $\omega=\gamma H$. In the experiments here described, we have used an easily saturable material and reduced the demagnetizing field to a low value. The standing wave ratio was determined in a resonant cavity for various values of the field which was varied from 200 to 10,000 oersteds, and this ratio was converted to apparent permeability with respect to the microwave field. A sharp resonance, about 100 oersteds wide at half-maximum, occurs at a field of 4920 and corresponds to a g of 2.17. This value is substantially above the value 2 for electron spin and is in disagreement with the more direct determinations of Barnett.

[1] J. H. E. Griffiths, Nature **158**, 670 (1946).
[2] C. Kittel, Phys. Rev. **71**, 270 (1947).

**E3. Relaxation Effects in Paramagnetic and Ferromagnetic Resonance.** CHARLES KITTEL,* *Massachusetts Institute of Technology.*—A discussion will be given of some theoretical[1,2] aspects of the paramagnetic[3] and ferromagnetic[4] resonance experiments. The resonance condition between frequency and d.c. magnetic field may depend on the line width, and the form of the dependence will vary according to the manner in which the relaxation frequency is introduced into the equations of motion. The *ferromagnetic* resonance experiments of Bozorth and Yager support the classical damping term as introduced by Frenkel. A discussion will be given of the effects of anisotropy and exchange interactions on the condition $\omega=\gamma(BH)^{\frac{1}{2}}$ for ferromagnetic resonance. There is a possibility of obtaining resonance in the anisotropy field of ferromagnetic single crystals. Exchange interaction effects enter when the penetration skin depth is small.

* Fellow of the John Simon Guggenheim Memorial Foundation.
[1] J. Frenkel, J. Phys. U.S.S.R. **9**, 299 (1945).
[2] C. Kittel, Phys. Rev. **71**, 270 (1947).
[3] E. Zavoisky, J. Phys. U.S.S.R. **10**, 197 (1946).
[4] J. H. E. Griffiths, Nature **158**, 670 (1946).

**E4. Magneto-striction of Annealed and Cold Worked Nickel Rods.** J. E. GOLDMAN, *Westinghouse Research Laboratories.*—Resistance strain gauges have been adapted to the measurement of the magneto-striction of polycrystalline rods and strips. Conventional advance wire gauges were used in a balanced d.c. Wheatstone bridge with a Rubicon photoelectric galvanometer as a detector, measurements being made by deflection. Isoelastic gauges have a greater strain coefficient of resistance but are not desirable in this case because of the pronounced magneto-resistance effect in isoelastic wire. The method permits the investigation of magneto-striction in the range from $5\times10^{-6}$ to $10^{-4}$ with considerable accuracy. Measurements have been carried out on annealed and cold-worked nickel rods of a high grade of purity. The measured saturation magneto-striction of the annealed nickel rod was $-34\times10^{-6}$ $\pm2$ percent in excellent agreement with the value calculated by Becker for polycrystalline nickel with random initial domain distribution. For the cold-worked rod a value of $-41\times10^{-6}$ was obtained. The difference between the values for the two states is explained on the basis of the residual stresses resulting from the cold reduction which produces a preferred domain orientation transverse to the direction of work. For such an initial state, the magneto-striction is greater. Quantitative estimates of both the domain anisotropy and stress anisotropy are possible.

**E5. A Permeameter for Magnetic Measurements on High Permeability Material.** W. J. CARR, JR., *Westinghouse Research Laboratories.*—A new type of permeameter is described for making magnetic measurements on soft magnetic materials. The novel feature of the method is in the measurement of magnetizing force. This is accomplished by placing a small measuring element, consisting of a high permeability core with a winding on it, very close to the surface of the test specimen. The core is energized with a.c. above the knee of its magnetization curve, and the second harmonic in the voltage is a measure of the $H$-field in the specimen. Values of $H$ from $10^{-2}$ to $10^{+2}$ oersteds can be measured on high permeability samples with geometries which heretofore prevented accurate measurements. Errors in the measurement are discussed, and the proper design for the measuring element is given.

**E6. The Electrical Behavior of Vacuum Evaporated Tellurium.** WAYNE SCANLON AND K. LARK-HOROVITZ,* *Purdue University.*—Tellurium shows certain anomalies in its electric behavior (Hall effect, thermoelectric power). The Hall effect is positive at low temperatures, becomes negative, and then again shows a reversal at high temperatures, remaining positive up to the melting point. X-ray investigation in vacuum from liquid air temperature to the melting point have show that there is no change in crystal structure of tellurium evaporated in vacuum. However, Dowell and Lark-Horovitz have found that tellurium heated in air does show new x-ray diffraction lines around 360°. Experiments with layers of tellurium evaporated in a high vacuum onto a mica strip with suitable electrodes for carrying current and probes for measuring resistivity and Hall effects show, that tellurium investigated from liquid air temperature up to about 300° in vacuum does not exhibit any of anomalies observed before. These samples behave similarly to other elementary

semiconductors (Ge, Si). Throughout the whole range of temperature the Hall effect of tellurium remains positive. The resistivity curves show an activation energy of the order of 0.039 ev at low temperature, and go through a maximum followed by a rapid decrease of resistance indicating the intrinsic range of the semi-conductor (activation energy about 0.36 ev). Layers of this type heated in air remain essentially unchanged but show increased resistivity and Hall effect. It seems, therefore, that the anomaly in electrical behavior usually observed in tellurium is not due to a complexity of levels of the semi-conductor itself, but rather to admixtures of foreign layers produced in the preparation of the material in the atmosphere.

* This work has been carried out with the aid of the Signal Corps.

**E7. Resistivity and Hall Constant of Germanium Samples at Low Temperatures.*** I. ESTERMANN, A. FONER AND J. A. RANDALL, *Carnegie Institute of Technology.*—The Hall Effect was measured on the same germanium samples for which resistivity measurements were reported earlier.[1] In the case of a strongly degenerate sample (0.04 at. percent Al added) in which the resistivity was nearly independent of temperature, the Hall constant remained also independent of temperature between 20° and 300°K, and was also independent of the field strength for fields between 1000 and 7500 gausses. Samples with smaller impurity content, for which the resistivity increases with decreasing temperature, show an increase in Hall constant on cooling from room temperature to liquid nitrogen temperature, apparently followed by a slight decrease on cooling to 20°K. Additional resistivity measurements were carried out with samples containing antimony and tin, prepared and selected like the others at Purdue University. The samples, with 0.04 at. percent Sb added, show essentially the same behavior as those containing small amounts of P or Al. The samples containing tin show a monotonic decrease of resistivity with decreasing temperature. The previously observed increase in resistivity[1] of some samples produced by repeated heating and cooling was found to be due to changes in contact resistance.

* Work done under contract with the Office of Naval Research.
[1] I. Estermann, A. Foner, and J. A. Randall, Phys. Rev. 71, 484, 1947.

**E8. Spreading Resistance Discrepancies and Field Effects in Germanium.*** RALPH BRAY, K. LARK-HOROVITZ, AND R. N. SMITH,† *Purdue University.*—Contact and spreading resistance determine the forward resistance of metal-Ge point-contact rectifiers. Theoretically the spreading resistance is $\rho/2d$; $\rho$-semiconductor resistivity, $d$-contact diameter. Above one volt the contact resistance contribution is negligible and the spreading resistance is then given by the slope of the current-voltage characteristic. However, the spreading resistance so determined on high resistivity ($\rho \sim 1$ ohm-cm) $n$-type Ge decreases with increasing voltage and is lower by factor ten or more than the value predicted from bulk resistivity.[1] The high current densities through the contact ($\sim$10 ma through $10^{-6}$ cm$^2$) suggest the possibility of field effects. Actually, the bulk resistivity (studied with exponential and constant current pulses) is field dependent and starts to decrease at fields of 100 volts/cm. The time constant of the field effects may be estimated from the progressive increase of spreading resistance with frequency (about 100 Kc).[2] Calculations were made relating at least qualitatively the spreading resistance discrepancies with field dependence measurements of bulk resistivity.

* This work was started under OSRD contract and is continued under Signal Corps contract.
† Now at Boeing Aircraft, Seattle, Washington.
[1] Experiments also show saturation of spreading resistance with increased load and contact area (R. E. Davis).
[2] H. J. Yearian, "Dependence of Forward Conductance and Back Resistance of High Back Voltage Germanium on Voltage and Frequency." NDRC report October, 1945.

**E9. Spontaneous Electrical Oscillatons in Germanium Crystals.*** S. BENZER, *Purdue University.*—Electrical oscillations in germanium-to-metal point contacts are usually ascribable to negative resistance characteristics or mechanical effects. However, when the metal point is placed at the edges of regions showing the photodiode** effect, strong oscillations of an apparently different nature occur in a circuit containing only a d.c. source and a resistor in series with the crystal. Above a critical voltage (for one polarity only), oscillations begin; the frequency increases from the order of $10^5$ c.p.s. at several volts to $10^6$ c.p.s. at higher voltages and is insensitive to external circuit reactances. The amplitude may approach the supply voltage and the waveform is usually non-sinusoidal. The frequency and amplitude are strikingly sensitive to illumination and temperature. For a contact at the edge of a photodiode region one would expect to find a thin "sandwich" of $N$-type germanium between metal and $P$-type germanium. Such a configuration would have a minimum in the potential of an electron which might lead to oscillations. R. Bray has recently observed similar oscillations with suitably etched $P$-type germanium crystals.

* Based in part on NDRC report 14-580, October 31, 1945.
** Phys. Rev. 70, 105(A) (1946).

**E10. Theory of Low Temperature Semiconductor Resistivity.*** V. A. JOHNSON AND K. LARK-HOROVITZ, *Purdue University.*—The resistivity of Ge semiconductors ($P$ and $N$ type) has been calculated for temperatures from 300°K down to about 14°K. Classical statistics have been used for temperatures above the degeneracy temperature $T_d$, and values for impurity scattering with Fermi statistics below $T_d$, using the new Hall coefficient values obtained at Carnegie Tech. Residual resistivities[1] calculated from Hall data agree with experimental values. The impurity resistivity $\rho_T$ is given by

$$\rho_T = \frac{3.05\times10^{-15} n}{T^{\frac{3}{2}}} \frac{\ln\left(1+2.88\times10^{7} n^{-\frac{1}{3}} T^2 x^2 m\right)}{J_2(\mu/kT)}$$

where $n$ = number of electrons/cm$^3$, $J_2$ = Fermi integral, $X_m$ = energy value maximizing conductivity integral. Graphical and numerical evaluation of the Fermi integral involved gives calculated resistivity curves in close agreement with observations.

* This work was supported by Signal Corps contract.
[1] See V. A. Johnson and K. Lark-Horovitz, Phys. Rev. 71, 374 (1947).

FRIDAY MORNING AT 10:00

Moyse Lecture Theatre

(G. B. PEGRAM presiding)

### *Invited Papers*

**G1. The Interaction between Electrons and Radiation.** F. J. BELINFANTE, *University of British Columbia.* (30 min.)

**G2. Methods in Raman Spectroscopy.** H. L. WELSH AND M. F. CRAWFORD, *University of Toronto.* (45 min.)

**G3. Review of the Topic of Cosmic-Ray Bursts.** H. CARMICHAEL, *Chalk River Laboratory, National Research Council of Canada.* (30 min.)

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FRIDAY MORNING AT 10:00

MacDonald Chemistry Laboratory, Main Lecture Theatre

(R. SMOLUCHOWSKI presiding)

### *Solid State*

**H1. Rectification Characteristics of an Oxide Cathode Interface.** W. E. MUTTER, *Massachusetts Institute of Technology.*—Fine wire probes embedded in the coating of an oxide cathode are used to measure the potential drop over the interface and coating under pulsed conditions for both directions of current flow through the cathode. In the case of cathodes prepared on a 5 percent silicon-nickel base and operated at 800°C, the interface voltage is 3 to 5 times greater when the cathode is emitting electrons than when it is receiving the same current density of electrons. With a pure nickel base, there is a relatively small interface voltage which is initially independent of the direction of current flow, but increases during 130 hours of operation and then also exhibits rectification properties. The electrical conductivity of the coating is independent of the current density and the direction of current flow. The use of pure nickel or 5 percent silicon-nickel has no effect on the measured value of the coating conductivity. At temperatures above 800°C the total potential drop over the interface and coating as determined from probe measurements is found to account for deviations from the space charge law observed in experimental diodes.

**H2. Some Electrical Properties of an Oxide Cathode Interface.** A. EISENSTEIN, *Massachusetts Institute of Technology*—When high thermionic emission currents are taken from oxide coated cathodes, voltages appear across the oxide coating and across the interface between the coating and base metal; the latter voltage often exceeds the coating voltage at temperatures below 1100°K. Under pulsed conditions the total voltage drop across the interface and coating, $V_{ic}$, is not negligible with respect to the applied cathode-anode voltage, $V_a$. The experimental voltage-current characteristics of a diode should show disagreement with the theoretical Langmuir-Child characteristic by an amount $V_{ic}$. The emission characteristics of oxide cathodes prepared on a 5 percent Si-Ni base metal (interface of $Ba_2SiO_4$) show this effect. The actual voltage which appears between the exterior surface of the oxide coating and the anode, $(V_a - V_{ic})$, can be deduced from measurements of the retarding potential required to stop electrons which pass through a small hole in the anode. Values of $V_{ic}$ thus obtained and at temperatures above 1100°K account for the observed deviations from the theoretical Langmuir-Child characteristic. At low temperatures the emission is no longer limited by space charge and the voltage gradient across the interface may reach $10^6$ volts/cm. An interesting and unexpected result of this experiment is that a small number of electrons arrive at the anode with energies up to $V_a$.

**H3. Photoelectric and Optical Properties of Cesium-Antimony Films.** J. A. BURTON, *Bell Telephone Laboratories.*—In an attempt to understand the unusually high quantum efficiency of Cs-Sb photoelectric surfaces (1), optical and photoelectric measurements were made in the spectral region from 2255A to 11,000A on a series of semi-transparent films. The optical constants were determined from reflection and transmission measurements. In the ultraviolet the high absorption coefficient (approximately $4.7\times10^5$ cm$^{-1}$) must be due to a fundamental absorption band and not to impurity centers. The films appear to be optically homogeneous, and photoelectric measurements with polarized light give the results expected for a volume photoelectric effect. By comparing the photoelectric emission for light incident on the vacuum

side of the films with that for light incident on the quartz side, the mean depth below the surface at which an absorbed quantum produces a photoelectron is estimated to be about 250A. Using this value and the observed optical constants the magnitude of the quantum efficiency and its dependence on film thickness can be explained if the internal quantum efficiency is approximately unity and if the photoelectrons can readily escape into vacuum.

[1] P. Görlich, Zeits. f. Physik **101**, 335 (1936).

**H4. Secondary Emission from Conducting Films of Tin Oxide.** H. E. MENDENHALL, *Bell Telephone Laboratories.*—In the search for stable secondary emitting surfaces over a wide range of bombarding voltages and operating temperatures, thin stannic oxide films deposited on Vycor, Pyrex and platinum by the Corning Glass Works have been studied. The ratio of secondary to primary electrons from a conducting film of tin oxides on an underlying Vycor (synthetic quartz) was low enough to prevent cumulative charging of the surface bombarded with electrons up to 5000 volts energy. The $\delta$ was only slightly above one for primary electrons with more than 300 and less than 1600 volts energy. The maximum value observed was 1.11 at 600 volts primary energy which compares with a $\delta$ of value of 2.1 for glass reported by W. Heimann and K. Geyer. This same type of conducting coating on platinum applied to about 3 interference rings in thickness was also used as a target for secondary electron production. An increase in $\delta$ ratio to a value 50 percent higher than those reported for clean platinum was observed. The $\delta$ was above one between 150 and 6000 volts and reached a maximum of 2.5 when the target was bombarded with 600 volts primary electrons. For a film of 6 interference layers in thickness, $\delta$ was above one between 60 and 5000 volts and reached a maximum of 3.25 at 640 volts after being heated to a temperature of 850°C.

**H5. Characteristics of Bridges between Metallic Contacts.** G. F. HULL, JR., AND W. BAER, *Dartmouth College.**—Bridges between separated platinum and gold contacts have been obtained in air and in vacuum. The bridges observed vary in length from $10^{-4}$ to $10^{-3}$ cm. Current-voltage characteristics of platinum and gold bridges show that the product of current and voltage is approximately constant for currents up to about 10 amp. For currents above 10 amp. the electrodes expand changing the bridge dimensions. Photomicrographs of the bridges show that the bridge dimensions remain constant within $\pm 10$ percent over the constant power portion of the bridge characteristic. The platinum and gold bridges melt and disappear at voltages across the bridges of about 0.64 volt for platinum and 0.42 for gold when measurements are made in vacuum. These voltages correspond to the melting temperatures of platinum and gold respectively, which agrees with contact theory.[1] The current-voltage bridge characteristics can be transformed into resistance-voltage characteristics which are then compared with the theory of contact temperature.

* Assisted by the Office of Naval Research.
[1] R. Holm and E. Holm, Wiss. Veröff. Siemens-Werk. **7** [2], 217 (1929).

**H6. Single Crystals of Barium Titanate.*** B. T. MATTHIAS, R. G. BRECKENRIDGE, AND D. W. BEAUMONT, *Massachusetts Institute of Technology.*—Barium titanate as a ceramic of high permittivity has been known for several years. During the past months it has been possible to synthesize single crystals for investigation of the dielectric properties.[1] As the growth out of the melt encounters considerable difficulties as far as crucible, temperature, and volatility are concerned, barium titanate crystals were grown out of molten barium salts or others. If equimolar parts of barium carbonate and titanium dioxide are dissolved in molten barium chloride, even with a very slow cooling rate extending over a couple of weeks, it is difficult to obtain decent crystals. For aqueous solutions it has been long known[2] that an excess of cations considerably improve crystal growth. For barium titanate it was possible to find an adequate composition with barium carbonate in excess such that with a cooling process of not longer than eight hours perfect crystals up to half a centimeter were obtained. In contradiction of Megaw,[3] these crystals did not have a center of symmetry as they are strongly piezoelectric. The dielectric behavior points towards a new, third kind of ferro-electrics in addition to Rochelle salt and the dihydrogen phosphates.

* The research reported herein was made possible through support of the Navy Department and the Army Signal Corps.
[1] H. Blattner, W. Merz, B. Matthias, and P. Scherrer, Experientia **III**, 4 (April, 1947).
[2] Yamamoto, Sci. Pap. Inst. of Phys. and Chem. Res., Tokyo, **35**, 228 (1939).
[3] H. D. Megaw, Proc. Phys. Soc. **58**, 133 (1946).

**H7. On the Classification of Phase Transitions.*** L. TISZA, *Massachusetts Institute of Technology.*—A classification of phase transitions is suggested which is more specific than the purely thermodynamical one based on the *order* of the transition. In general, phases correspond to separate regions in phase space. A transition is said to be of the *first kind*, if the separation is realized in ordinary space, and of the *second kind* if it occurs in another subspace of phase space. For transitions of the first kind, the phase rule is valid. Examples are the gas-liquid-solid transitions and those polymorphisms in which the solid phases have unrelated symmetries. These transitions are all of the *first order*. There are, however, transitions of the first *kind* and *second order*, where in the course of thermal expansion a symmetry element appears or disappears ($\alpha-\beta$ transition of quartz, $BaTiO_3$, etc.) In transitions of the second *kind*, the phase rule is not valid and the transition is gradual ($\lambda$-anomaly of the specific heat.) The question of physical interest is to establish the nature of the phases which appear mixed. There are a great variety of cases partly not yet understood. These transitions are usually of the *second order*, although cases of *first order* transitions arise too. Examples are ferromagnetism, liquid helium, superconductivity, order-disorder transitions, rotational transitions, etc.

* This research has been supported in part by a joint Army-Navy Contract.

**H8. Solubility Gaps in Simple Binary Systems.** A. W. LAWSON, *University of Chicago.*—By expanding the second

derivative with respect to mole number of the free energy of a two-component phase near its critical point $(T_c, x_c)$ in a Taylor's series of the form $-a(x-x_c)^2+b(x-x_c)(T_c-T)+c(T_c-T)$, one may develop approximate expressions for the various thermodynamic quantities. The constants $a$, $b$ and $c$ are evaluated by satisfying the critical conditions and the requirement of complete segregation at absolute zero of temperature. Integration yields an expression for the chemical potential of the form,

$$\mu_1=a[(x^2/2)-[2x_c+(1-2x_c)(1-T/T_c)]x+x_c^2(T/T_c)\ln x]+\text{const.}$$

with a similar expression for $\mu_2$ in terms of $y$. Numerical solution of the two simultaneous equations $\mu_1(x_1)=\mu_1(x_2)$ and $\mu_2(1-x_1)=\mu_2(1-x_2)$ yields the equilibrium values of $x_1$ and $x_2$ delineating the solubility gap. This zero-order approximation thus yields a set of universal curves for solubility gaps as a function of the reduced variables $T/T_c$ and $x/x_c$. The curve $x_c=0.5$ agrees with that computed from Bragg-Williams theory, and fits experimental curves somewhat better than a similar approximation discussed by Hildebrand.

**H9. The Wiedemann-Franz-Lorenz Ratio for Copper Alloys.** R. RUEDY, *National Research Council of Canada.*—A study of the values obtained for the electrical and thermal conductivities of 10 copper-aluminum, 8 copper-nickel, 8 copper-silicon, 8 copper-manganese, and 50 miscellaneous ternary and quaternary alloys of copper with zinc, tin, lead, manganese, iron, and nickel, measured at different temperatures by C. S. Smith and E. W. Palmer,[1] shows that after subtraction of a constant amount of non-electronic thermal conductivity, the Wiedemann-Franz-Lorenz ratio of all the alloys is in closer agreement with the Lorenz constant given by Sommerfeld's theory of conductivity than with Drude's value for metals. The decrease in the thermal conductivity of copper, caused by a small concentration of another metal in solid solution, is independent of the temperature between at least 40 and 230°C.

[1] Trans. A.I.M.E. 117, 225-243 (1935).

**H10. The Structure of Manganese-Rich Alloys of Copper and Manganese.*** FRANCIS T. WORRELL, *University of Chicago.*—Manganese-copper alloys containing more than 82 percent manganese have, when appropriately heat treated, a face-centered tetragonal structure (1) with an axial ratio varying from 0.937 for pure manganese to 1.00 (i.e., face-centered cubic) at 82 percent manganese. Alloys in this range often have high internal friction. Zener (2) has suggested that the damping results from the relaxation of stresses across the {101} and {011} interfaces of twins associated with a tetragonal structure. Metallographic examination of the alloy 88 percent manganese, 12 percent copper shows a duplex twin structure, consisting of large twins, such as one finds in face-centered cubic metals, with a fine twin pattern superposed. This structure has been analyzed. The large twins are along the {111} planes, and the fine ones are the postulated tetragonal twins. This analysis has been confirmed by x-ray studies. Possible explanations of this structure will be discussed.

* This research was supported by O.R.I.
[1] Persson, Zeits. f. physik Chemie **B9**, 25 (1930).
[2] Private communication to the author.

**H11. On the Theory of the Use of Isotopes as Tracers.** HERMAN BRANSON, *Howard University.*[1]—It is shown that an integral equation can be established which describes some of the important features of chemical and biological systems in which stable and radioactive isotopes are used as tracers. The equation is

$$M(t)=M(0)F(t)+\int_0^t R(\theta)F(t-\theta)d\theta$$

where $M(t)$ is the amount of the substance present at time, $t$; $R(t)$ is the rate of accumulation, and $F(t)$ is called the "metabolizing" function: that function which multiplies the original amount to give the amount remaining at time, $t$. Some of the data from experiments with $I^{131}$ and $P^{32}$ are discussed. The experimental procedures for determining properties of biological and chemical systems are shown to yield the functions in the equation. Specific experiments with single and double tracer molecules in progress in our laboratories are mentioned.

[1] Placed on Friday at the author's request.

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## FRIDAY AFTERNOON AT 2:30

Moyse Lecture Theatre

(W. B. LEWIS presiding)

### *Invited Papers*

**I1. Diffusion of Neutrons.** G. PLACZEK, *Chalk River Laboratory, National Research Council of Canada.* (45 min.)

**I2. Ion Sources.** A. G. WARD, *Chalk River Laboratory, National Research Council of Canada.* (45 min.)

**I3. Progress Report and Plans for the McGill University Cyclotron.** J. S. FOSTER, *McGill University.* (30 min.)

## FRIDAY AFTERNOON AT 2:00

MacDonald Chemistry Laboratory, Main Lecture Theatre

(P. DEMERS presiding)

### *Solid State*

**J1. New Results at Pressures up to 100,000 kg-cm$^2$.** P. W. BRIDGMAN, *Harvard University.*—A number of improvements have been made in the apparatus for measuring volume decrements up to 100,000 kg/cm$^2$. It is now possible to carry seven insulated leads into the external pressure chamber, in which a pressure of 25,000 to 30,000 kg/cm$^2$ prevails, to support the piezometer for 100,000. With this increased number of leads it is possible to make measurements of both change of volume and compressive force from the inside of the supporting chamber instead of from the outside, and thus avoid several corrections arising from distortion of the pressure vessels. With this apparatus measurements on thirty new substances have been made to 100,000. The most interesting result is a reversible volume discontinuity in caesium near 50,000 of about 17 percent. The explanation of this is not clear, since already, below 50,000, caesium has assumed the close-packed arrangement. It probably means some deep-seated rearrangement within the atom.

**J2. Impingement and Stimulation in Grain Growth.** R. SMOLUCHOWSKI, *Carnegie Institute of Technology.*—The usual assumption concerning the process of recrystallization is that new recrystallized grains start growing at random within the deformed metal and grow with a definite rate until all material is recrystallized. It has been variously suggested that there is stimulation, i.e., a growing grain increases the probability of the occurrence of a new center of recrystallization in the proximity of its boundary. In particular Burgers suggested that such stimulated grains have a particular crystallographic relationship to the original grain. By means of an analysis of the shapes of recrystallized grains in aluminum it has been possible to deduce what was the radius $r$ of the original grain, while the new grain was starting to grow within the distance $n$ from the boundary of the original grain. Also, it was possible to estimate the ratio of the rates of growth of neighboring grains. The results indicate an effect which may be interpreted either as stimulation or as an unstability of small grains relative to large grains. The latter possibility is supported by the presence of grains which have a shape indicating a growth of the larger grain at the expense of the smaller grain.

**J3. Studies in Friction II. Maximum Shear Strength of Solids in Relation to the Thermodynamics of Melting.** M. EUGENE MERCHANT, *The Cincinnati Milling Machine Company.*—It appears that the *maximum* shear strength of a solid (i.e., its shear strength when behaving as an isotropic material) is related to its melting properties. The process of shear can be crudely treated as stress-activated melting in one degree of freedom. When this is done, the resulting thermodynamic equation relates the maximum shear strength to the density, heat of fusion, and melting point of the solid. The calculated values are useful in cases where the process of shear is restrained from following preferred crystal planes (as in severely cold-worked materials or in thin films on friction surfaces), and where relative rather than absolute values are of most importance. Such calculations have previously been applied to the interpretation of the friction of clean metals.[1] In the present case they have been studied in relation to thin films of solids on friction surfaces, as found, for instance, under conditions of boundary lubrication. Calculated values also are compared with experimental data obtained by Bridgman.[2] A fair degree of correlation exists.

[1] H. Ernst and M. E. Merchant, Proc. Spec. Summer Conf. on Friction and Surface Finish (MIT), 76–101 (1940); *Surface Treatment of Metals* (Am. Soc. for Metals, 1941), pp. 299–337.
[2] P. W. Bridgman, Proc. Am. Acad. **71**, 387–460 (1937); Phys. Rev. **48**, 825–847 (1935); J. App. Phys. **8**, 328–336 (1937).

**J4. Speed of Propagation of a Fracture Crack in Metals.** EDWARD SAIBEL, *Carnegie Institute of Technology.*—Recently the author has proposed a thermodynamic theory of the fracture of metals[1] which relates fracture to the melting phenomenon. From this point of view and with the use of the Eyring "hole" theory of the liquid state, the rate of formation of the "hole" structure is calculated from chemical reaction rate theory, the reactant being the material before fracture and the product of the reaction being the holes. Since the abolition of cohesive strength is attributed to the formation of the holes, the rate at which they are formed gives directly the rate of propagation of the crack. The effects of temperature and of stress system are also indicated. Using the data of reference 1, it is found that the speed of fracture of a mild steel plate at room temperature, under a tensile stress, is about 75,000 in./sec. Some experimental work[2] done along these lines shows values of the same order of magnitude.

[1] E. Saibel, Metals Technology **14**, 1 (February 1947).
[2] M. Greenfield and G. Hudson, Proc. Nat. Acad. Sci. **31**, 150 (1945).

**J5. Atomic Vacancy and the Viscosity of Grain Boundaries in Metals.*** T'ING-SUI KÊ, *The University of Chicago.*—As will be reported in *The Physical Review*, the grain boundary in metals behaves in a viscous manner in the sense that it cannot sustain a shear stress and has a coefficient of viscosity decreasing with an increase of temperature. Recently it has been found by internal friction measurements on 99.991 aluminum specimens of similar grain size that the grain boundary viscosity is lower in a specimen subjected to a heavier plastic deformation prior to

recrystallization. It has also been found that the conditions corresponding to a smaller grain boundary viscosity in this metal are conditions that favor grain growth. These and other observed phenomena can be adequately explained by assuming that atomic vacancies or holes are created during plastic deformation and that they "migrate" to the grain boundaries during later heat treatment, as was originally conceived by Hollomon. The accumulation of holes at the grain boundaries should reduce the grain boundary viscosity. According to these assumptions, the heavier the previous deformation, the greater will be the hole density at the grain boundary, and thus the lower the grain boundary viscosity. The larger hold density at the grain boundary favors grain growth because of the associated increase of surface energy.

* This research was supported by ORI.

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## SATURDAY MORNING AT 10:00

MacDonald Physics Laboratory, Room 102

(A. N. SHAW presiding)

### *Optical and Photographic*

**M1. The Optical Aberrations of the Eye and Night Myopia.** M. J. KOOMEN AND R. TOUSEY, *U. S. Naval Research Laboratory.*—It is well known that the human eye becomes somewhat myopic for fields of low brightness. The effect was measured by determining acuity thresholds for the eye with spectacle lenses of different powers placed before the eye, and for white fields ranging from very bright to as low as 0.005 microlambert. From the optimum lens corrections for each brightness level a curve was derived showing diopters of myopia *versus* field brightness. The magnitude of the effect was found to be as much as $-2$ diopters. Chromatic aberration, foveal and extra-foveal spherical aberration, and pupil diameters were measured for the same observers. It was shown that chromatic aberration along with the Purkinje Effect accounts for only about $-0.25$ diopter myopia and the remainder is largely caused by extra-foveal spherical aberration and the Stiles-Crawford Effect. The eye aberrations were sufficient to account for the observed myopia and it was not necessary to postulate accommodation at low brightness levels.

**M2. Calculation of Index of Refraction of Water Vapor in the Far Infra-Red.** F. W. BROWN AND M. A. GREENFIELD, *North American Aviation.*—Optical calculations for instrumentation in the far infra-red are handicapped by lack of experimental data on index of refraction of water vapor beyond $0.7\mu$. Calculations of the index of refraction were made using the following idealizations of absorption bands: (1) lines in a band are equally spaced and have equal half-widths; (2) all lines in central portion of band have equal intensities. The classical dispersion formula for index of refraction, $n$, at the frequency, $\nu$, becomes

$$n-1 \doteq \Sigma \frac{S_i}{\pi d_i} \ln \left[ \frac{(\nu_{0i}-\nu+\Delta\nu_{0i})^2+\alpha^2}{(\nu_{0i}-\nu-\Delta\nu_{0i})^2+\alpha^2} \right]^{\frac{1}{2}} \cdot \frac{\nu_{0i}+\nu-\Delta\nu_{0i}}{\nu_{0i}+\nu+\Delta\nu_{0i}}$$

where $\nu_{0i}$, $\Delta\nu_{0i}$ are respectively the average frequency and half-width of $i^{th}$ band, $\alpha$, $d_i$ are, respectively, the half-line width and average spacing between lines of a band. Values of $S_i$, the average line intensity, were obtained from known values of the macroscopic coefficient of absorption, using a derived theoretical expression for the absorption of a band. A qualitative estimate was made of the contribution to the index of refraction by the weak absorption lines near the edges of the band.

**M3. The Hyperfine Structure of the Ammonia Inversion Spectrum in an Electric Field.** J. M. JAUCH, *State University of Iowa.*—The ammonia inversion spectrum shows a hyperfine structure due to the electric quadrupole moment of the nitrogen nucleus.[1] The sensitivity of the microwave absorption measurement can be increased by modulating the frequency of the absorption lines by putting the sample into a variable uniform electric field $E$.[2] In order to observe any effects due to the nuclear spins it is necessary to stay within a field region for which the spin is not completely decoupled from the angular momentum. The quantum-mechanical treatment of the problem leads to a secular equation of third order which can be factored for all values of $J$ and $K$, for $M=J$, $J-1$, and 0. For the other cases good approximations are obtained by treating the problem with second-order perturbations for weak and strong fields, respectively, and interpolating numerically for the intermediate region ($E\sim 300$ volt/cm). Strong departure from expected displacements proportional to $E^2$ can occur already at weak fields because of strong perturbations of combining levels. A complete level scheme will be given for the strongest line $J=K=3$.

[1] Dailey, Kyhl, Strandberg, Van Vleck, and Wilson, Phys. Rev. 70, 984 (1946).
[2] R. H. Hughes and E. B. Wilson Jr. Phys. Rev. 71, 562 (1947).

**M4. The Structure of the *D*-Terms of $Li^9$.** K. W. MEISSNER AND L. G. MUNDIE,* *Purdue University.*—The wave-length material of the arc spectrum of lithium available at the present is rather incomplete and the values

not sufficiently accurate for drawing reliable conclusions regarding the fine structure of the $D$-terms. Therefore, we made new interferometric measurements employing an atomic beam source. The structure of the $n^2D$-terms ($n=3, 4, 5$) revealed regular term order, the splitting being 0.037 $cm^{-1}$, 0.020 $cm^{-1}$, and 0.008 $cm^{-1}$ respectively.

* Now at the Naval Ordnance Laboratory, Washington, D. C.

**M5. Infra-red Spectra of Argon, Krypton, and Xenon between 1.15 and 2.25 Microns.** W. R. SITTNER AND W. S. HUXFORD, *Northwestern University.*—Infra-red spectra emitted by high intensity condenser discharge sources have been recorded. The discharge tubes were designed and constructed in this laboratory. A 1½-inch plane reflection grating, having 15,000 lines per inch, was used. The detector was a lead sulfide photoconductive cell feeding into a broad band amplifier. The amplifier operated a photoelectric paper strip recorder. The probable error in determining wave numbers of lines near $2\mu$ is less than 2 $cm^{-1}$. Eleven strong and 9 weaker lines were found in the argon spectrum in this region. Of these, seventeen lines were observed for the first time. Thirty-eight lines, consisting of 18 strong and 20 weaker ones, were found in krypton. Twenty-eight of these are new lines. Seventeen lines were found in xenon. Thirteen was strong and four were weak. Sixteen of these were observed for the first time. Most of the spectral lines observed in argon and krypton are due to combinations of terms of the normal atom given by Meggers and Humphreys.[1] The xenon lines are similarly identified, except that the addition of the $2s_2$-term, (12393.9 $cm^{-1}$, $j=1$) is required.

[1] Bur. Stand. J. Research **10**, 427 (1933); **10**, 139 (1933).

**M6. Electrophotography.** R. M. SCHAFFERT AND C. D. OUGHTON.—An entirely new photographic process, which does not involve the use of film or chemical solutions, has been developed. The process, known as electrophotography, employs a plate consisting of a thin photoconductive layer on a conductive base. The plate is sensitized by electrostatic charging, and after exposure, the image is developed by dusting the plate with micronized powder. Prints are made by transferring and fixing the powder image to paper or other materials. The plate can be re-used numerous times. The paper describes the fundamental principles of the electrophotographic process, and directs particular attention to its applications.

**M7. The Silver Bromide Grain of Special Photographic Emulsions.** W. KNOWLES, *McGill University*, AND P. DEMERS, *Chalk River.*—Using an electron microscope, the grains of several undeveloped emulsions useful in nuclear physics, and of a few others, were examined. They appear as regular hexagons of rather uniform size. Here are the approximate diameters: Eastman 548, $0.03\mu$; our formula II, 0.04 to $0.08\mu$ according to lot examined; Ilford D, $0.12\mu$, $-C_1$ and $C_2$, $0.16\mu$; $B_1$, $0.21\mu$: Eastman V-O, $0.25\mu$; $-\alpha$, $0.28\mu$; —Microfilm, $0.42\mu$; —Lantern slide, $0.6\mu$. The grains ought to be flat, thickness being probably about ¼ diameter. About half the grains carry a bump and sometimes a horn protruding on one side, which is thought to be the visible image caused by the electrons. A layer of adsorbed gelatine $0.01\mu$ thick is visible around the grains. The closely packed grains in our concentrated emulsions never showed a long protruding ribbon as visible in Lippman emulsion, on development; instead, as seen in one picture obtained of an $\alpha$-ray track at these high magnifications, each developed grain viewed as a unit in the optical microscope arises from some 30 Ag Br grains developed around the one carrying the impression.

* Now at the University of Montreal.

**M8. Regression of the Latent Image of Nuclear Tracks in the Photographic Emulsion.** J. LAPALME AND P. DEMERS, *University of Montreal.*—Plates were irradiated with $\alpha$-rays and protons, kept at room temperature for 0 to 120 days (8 to 14 months in some cases), and developed in D19 at 20C 5 minutes: Eastman $\alpha$, V–O, Ilford D1, C1, C2, D1, and 15 minutes: Eastman 548, and our own formula II.[1] In every case fading of the track is perceptible after less than a day, it is severe after a month especially for protons. Grain spacing $\Delta$ in $\alpha$-ray tracks follows this approximate equation at first: $1/\Delta \sim \exp -(t/T)^{\frac{1}{2}}$; with $T=5$ to 50 days, according to ionizing power, and to emulsion used, but the general law is not so simple. Fading is much faster at 42C; at −85°C it is too slow to be observed in several months. Sensitivity also is observed to increase with temperature. Fading should be due in part at least to "evaporation" of active specks in Ag Br crystals. These findings are important for interpreting cosmic-ray data concerning number and grain density of tracks. On the other hand, age of tracks can be estimated from their density, sometimes within a few hours.

[1] Demers, Can. J. Research (to be published).

**M9. Radioactive Stars Showing Migration of Single Nuclei in the Photographic Emulsion.** PIERRE DEMERS, *University of Montreal.*—Some of our plates, kept 5 months between making and developing, showed a splitting of the well-known five-branched thorium stars, for instance the $\alpha$-ray of Rd Th and that of Th X radiating from one point, and those of Tn, Th A, and Th C′ from another point as far as several microns away from the first. This is interpreted as showing the migration of a Tn nucleus from the point where it was formed to the point where it decayed. Such a conclusion was confirmed by a study of plates containing added Th or Ra developed after a few days, through range and age (see next abstract) determinations. In some instances, one star out of 10 showed on close scrutiny at least the minimum perceptible displacement (0, 1–0, $2\mu$) between the centers of emission. Displacements have been observed showing the occasional migration of the following nuclei: Rn, Tn, Th A, Th B or C, or C′. The importance of such migrations seem large in view of the short periods and delays involved. They are greater than the recoil ranges. Probably the heterogeneous structure of the emulsion provides in places paths of easier motion.

SATURDAY MORNING AT 10:00

Moyse Lecture Theatre

(R. SMOLUCHOWSKI presiding)

***Committee on Solid-State Physics***

***Symposium on the Solid State***

**Q1. Diffraction of Neutrons in Crystals.** F. SEITZ, *Carnegie Institute of Technology.* (40 min.)

**Q2. Theory of Crystal Rectifiers with Application to Copper Oxide.** J. BARDEEN, *Bell Telephone Laboratories.* (40 min.)

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SATURDAY AFTERNOON AT 2:15

Moyse Lecture Theatre

(F. SEITZ presiding)

***Symposium on the Solid State (continued)***

**R1. The Relaxation Spectrum of Metals.** CLARENCE ZENER, *University of Chicago.* (40 min.)

**R2. Nuclear Magnetic Resonance Absorption in Solids and Liquids.** E. M. PURCELL, *Harvard University.* (40 min.)

**R3. Conductivity Pulses Induced in Diamond by Alpha-Particles.** A. J. AHEARN, J. A. BURTON, AND K. G. MCKAY, *Bell Telephone Laboratories.* (30 min.)

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SATURDAY AFTERNOON AT 2:15

MacDonald Physics Laboratory, Room 102

(H. J. C. IRETON presiding)

***Theoretical and Miscellaneous***

**S1. On the Nuclear Mass Defect.** GERTRUDE SCHWARZMANN, *New York City.*—Interpretation of particle waves as alternating currents with direct current components allows for interpreting dematerialization as superposition of, and materialization as decomposition of a light wave into a pair of particle waves, and is based on the following assumptions: The entities of both light and matter exist as corpuscles and as waves. Transitions of corpuscles into waves occur in electromagnetic fields, those of waves into corpuscles in field-free regions. The direct current component of the wave is equal in magnitude and sign to the direct current conveyed by the associated corpuscle. Wave and associated corpuscle have equal velocities, frequencies, and energies. Two particle waves, having equal velocities, frequencies, and direct current components equal in magnitude and opposite in sign, are a pair of particle waves. Interpretation of mass defect of any satellite as the mass equivalent of its negative energy, and of the neutrons as atoms, allows for interpreting the nuclear mass defect as the sum of the mass defects of the intranuclear satellites. Computed from this angle the magnitude of the force of attraction between central body and satellite in the neutrons explains why positrons and negatrons are observed but *in statu nascendi*, even if materialization and dematerialization occur by equal pairs.

**S2. Continuous particles.** M. HESSABY, *Teheran (now at Institute for Advanced Study).*—A reinterpretation of Maxwell's equations in general relativity leads to the deduction of a metric tensor for the field of an uncharged particle which yields a finite density of energy at every point in space, the integral of the energy over the whole

of space being equal to the mass of the particle, which thus appears to be a continuous distribution of energy through space. An expression is deduced for the electrostatic field of an electron giving charge and energy densities which are finite at every point in space, the integrals over the whole of space being respectively equal to the charge and to the mass of the electron. An indication is found of the possibility of an attraction between two positive charges in a certain range of distances, and of the possibility of an attraction between a positive charge and an uncharged mass. The consideration of a certain solution of the wave equation of Maxwell's theory leads to the notion of a harmonic spherical wave surroundings a particle in motion. This leads to a new interpretation of Schrödinger's equation.

**S3. Integral and Rational Eigenvalues in the Nuclear Domain and their Significance.** ENOS E. WITMER, *University of Pennsylvania.*—The writer[1] has shown that the known nuclear eigenvalues appear to be integral (in the ground state of stable nuclei) or rational multiples of a natural unit for that particular physical quantity. It seems altogether improbable that this result could be obtained from any theory of nuclei in which the constituent particles are held together by forces which are continuous functions of continuously varying space coordinates, *even with quantum-mechanics.* It seems probable that the observed results can be obtained only from some theory in which all the quantities involved are rational or integral numbers. This seems to point to the necessity of "quantizing" the space and time coordinates. We use the word "quantization" here to refer to any theory which by its very nature implies the existence of a minimum measurable distance and/or gives a discrete character to space-time. The number 42, which appears to play an important role in connection with nuclei and elementary particles, possibly derives its importance from the fact that space is three-dimensional. Note also that the Riemann-Christoffel tensor of general relativity has 21 (one-half of 42) *distinct* components.

[1] E. E. Witmer, Proc. Nat. Acad. Sci. **32**, 283 (1946).

**S4. On the Recurrence-Time Probability for the Harmonic Oscillator in the Limit of Vanishing Mass.** A. J. F. SIEGERT, *Syracuse University.*—The differential equation for the coordinate $y(t)$ of a harmonic oscillator in Brownian motion as a function of time reduces to first order for vanishing mass, so that in this limit $y(t)$ becomes Markoffian in the ordinary sense. The recurrence-time probability $w(a/t)dt$, i.e. the probability that $y$ returns to a value $a$ for the first time after $a$ time between $t$ and $t+dt$, becomes singular at $t=0$, but one can define the probability $q(a/t)dt$ that—for a time instant $t_0$ chosen at random—the largest time interval, which contains $t_0$ but no roots of the equation $y(t')=a$, is of duration between $t$ and $t+dt$. If both $w(a/t)$ and $q(a/t)$ exist, we have $q(a/t)=(t/\bar{t})w(a/t)$ where $\bar{t}=\int_0^\infty tw(a/t)dt$. This equation can be used to obtain the recurrence-time probability for the harmonic oscillator when the mass approaches zero at fixed $t>0$, since $\bar{t}$ is known for the general case,[1] and $q(a/t)$ can be obtained from the known first-passage time probability for Markoffian random functions.[2]

[1] S. O. Rice, *Mathematical Analysis of Random Noise*, p. 63.
[2] A. J. F. Siegert, Phys. Rev. **71**, 485 (1947).

**S5. Theory of the Increase in Rigidity of Rubber During Cure.** HUBERT M. JAMES AND EUGENE GUTH, *Purdue University, and University of Notre Dame.*—The rigidity of rubber, considered as a network of flexible molecules with Gaussian configuration functions, can be calculated when certain statistical features of the network are specified. In particular, it is sufficient to know the distribution of lengths and vector-mean extensions of the network segments. The assumption that the vector-mean extensions have Gaussian distributions corresponds to a similar postulate in the theory of Wall, and leads to the same proportionality between rigidity and the number $G_a$ of segments per unit volume in the "active" part of the molecular network. Consideration of the process of cure shows that this assumption cannot be expected to be correct, though it gives results of the right order of magnitude. As an alternative approach to the problem we have studied the increase in rigidity as cure proceeds, using a more realistic picture of the process of cure than those hitherto employed. The final result resembles that given by earlier theories, except that $G_a$ is replaced by $B_a$, the number of bonds formed within the network during cure. Since $B_a$ is smaller than $G_a$ by a factor of 2 or more, this theory leads to the prediction of lower rigidities per bond formed.

**S6. Further Simplifications in the Derivation of Thermodynamical Relations.** H. KAUFMAN AND A. NORMAN SHAW, *McGill University.*—A brief review of the usefulness of Jacobians in simplifying thermodynamical analysis, in obtaining new results, and in teaching. An account of a recent application to a system involving electric and magnetic fields.

**S7. Minimum Sparking Potentials of Barium, Magnesium and Aluminum in Xenon.** HAROLD JACOBS AND ARMAND P. LAROCQUE, *Sylvania Electric Products.**—The minimum sparking potentials of Ba, Mg, and Al in xenon are determined and found to be $82\pm2$V, $120\pm1$V and $151\pm2$ volts, respectively. The regulation voltages are measured in the tubes studied and found to be $67\pm1$V, $111\pm1$V, and $135\pm3$V, respectively. A rough calculation of $\gamma_m$, the ratio of electrons liberated per positive ion bombarding the cathode at the minimum sparking potential, is made and a relationship found such that lower work functions for the three metals indicate a higher $\gamma$.

* This work was undertaken in association with the Applied Physics Laboratory of the Johns Hopkins University and sponsored by the United States Navy.

**S8. Interference Patterns on the Walls of Tubes Carrying High Frequency Discharges.** R. W. STEWART, J. I. LODGE, AND J. K. ROBERTSON, *Queen's University.*—Under certain conditions, deposits exhibiting interference patterns are thrown down on the walls of tubes carrying high frequency discharges in air and other gases. The

index of refraction of these deposits, as measured by a new method, has the value $1.487 \pm 0.003$ for tubes of Pyrex glass and quartz, with carrier gases, air, and helium. It is concluded that the deposits are silicon dioxide, in the form of cristobalite. Similar measurements for polystyrene tubes give values of the index which are a function of the thickness of the deposit, and range from 1.25 to 1.35. In this case it is considered that the deposits are polystyrene, the variation in the index being ascribed to changes in density.

**S9. Structural Absorption of Sound in Water.** LEONARD HALL, *Brown University.*—Structural relaxation is found capable of accounting for the excess ultrasonic absorption in water. It implies a coefficient of bulk viscosity for water several times greater than that of shear-viscosity. Approximate calculation of the ultrasonic absorption coefficient reproduces reasonably well the temperature variation experimentally observed by Fox and Rock in the range 0–30°C and preliminary measurements made in Brown Laboratory by Smith in the range of 30–80°C. During compression of a liquid the molecules are brought uniformly closer together and also rearranged or repacked more closely. The former process is relatively rapid and may be considered instantaneous. The latter structural compression involves the breaking of intermolecular bonds, lags the applied pressure, and leads to absorption. A relaxation treatment may be applied to the structural compression. The acoustic wave perturbs molecular transitions to and from the sites of closer packing through the work performed by or against it in the volume change. The activation energy determining the rate of transition should be close to that for shear viscous flow and the configuration of closer packing, approximately that of closest packing. The structural absorption can be conveniently expressed by a temperature dependent factor times the shear viscosity absorption.

**S10. Impedance of Biological Cells at Microwave Frequencies.** T. M. SHAW, D. E. JAMISON, AND J. A. GALVIN, *Western Regional Research Laboratory.*—Very little data exist on the dielectric properties of biological materials in the microwave region. In the present work, the loss factor and dielectric constant of aqueous suspensions of yeast cells (*Saccharomyces cerevisiae*) were measured at $3.3 \times 10^9$ c.p.s. The results were correlated with existing data at lower frequencies. The impedance measurements were made according to a scheme used by Knerr and by Cooper, with a modification whereby a resonant section of waveguide was substituted for the parallel wire transmission line used by them. It was thus possible to reduce to less than one-tenth the amount of suspension used in the measurements and to eliminate errors caused by stray fields. The measurements show that the dielectric constant, $\epsilon'$, of a suspension of yeast cells at $3.3 \times 10^9$ c.p.s. can be expressed by the equation, $\epsilon' = \epsilon_0' - CK$ for yeast concentrations of 0 to 20 percent by volume. Here, $\epsilon_0'$ is the dielectric constant of the suspension medium (water or salt solution), $C$ is the concentration of yeast, and $K$ is a constant. The loss factor is practically identical with that of the suspension medium. By the use of the Cole circle diagram, the present results are shown to be consistent with a proposed electrical model of biological cells.

**S11. The Measurement of Rainfall by Radar.** J. S. MARSHALL, R. C. LANGILLE, W. M. PALMER AND D. W. PERRIE.—The power of radar echoes from rain has been observed to be proportional to $\Sigma D^6$, the drop-diameters to the sixth power summed over unit volume. This is in agreement with theory, but the power of the echoes is probably many times greater than theory indicates. Empirically, $\Sigma D^6$ is found to be nearly proportional to $R^2$, where $R$ is the intensity of rainfall.

## SUPPLEMENTARY PROGRAMME

**SP1. Regularities in the Properties of Metallic Elements.** R. SMOLUCHOWSKI, *Carnegie Institute of Technology.**—A relation between metallic properties and the atomic structure of the elements is as a rule quite complicated because of the specific character of electronic interactions in metals, and also because of the complex nature of some of the relatively easily measured properties. Among others, the Poisson's ratio, as pointed out by Köster, shows certain regularities in the periodic system. These are considered in a qualitative manner from the point of view of the repulsion between ions due to overlap and electrostatic forces between ions and valence electrons. The anomaly in the ferromagnetic group is discussed. Further, the differences and similarities of properties in the copper, silver, gold group are considered.

* To be called at the end of Session H if time permits.

**SP2. New Autoradiographic Method.** P. DEMERS AND V. FREDETTE, *Université de Montréal.**—It should be possible to cover or surround a microscopic sample on section containing a radioactive $\alpha$-emitter, carried on a glass slide, with an emulsion sensitive to $\alpha$-ray tracks, and after drying, waiting and developing, and eventual staining of the specimen, to see simultaneously under the microscope the detailed structure of the cell, or crystal, etc., and the $\alpha$-tracks at the same time, coming from the spots where the radioactive substance was present. Identification of the region in the structure which contains or retains certain molecules or nuclei, becomes feasible, with great accuracy. This method has been successfully applied with our new emulsions to microbe cells retaining Ra $SO_4$. (Clusius, Coccus, Saccharomyces, etc.). The track may designate its origin in or on the cell within 0.1–0.2$\mu$.

* To be called at the end of Session M if time permits.

## TO BE READ BY TITLE

**T1. Near Infra-red Spectra of the Planets.** ARTHUR ADEL, *University of Michigan.*—Kuiper, Wilson, and Cashman have recently recorded low dispersion spectra of several stars and planets, employing a lead sulfide cell in the region 0.75–2.6 mu.[1] Carbon dioxide bands appear in the spectrum of Venus at 2 and 1.6 mu, and the spectra of Jupiter and Saturn are cut up by extremely heavy bands. The authors are aware of the probable origin of these bands in methane and ammonia, but add that, "laboratory intensities are still lacking." It seems worth while, in this connection, to describe some unpublished curves recorded in conjunction with experiments bearing on water cell temperatures and planetary atmospheres.[2] Glass prismatic solar spectra were obtained through large concentrations of carbon dioxide, methane, and ammonia. The principal regions of absorption are: $CO_2$: 2, 1.6, 1.2 mu;[3] $CH_4$: 2.5–1.7, 1.4, 1.17, 1.01, 0.88, 0.80;[4] $NH_3$: 2.5–2.1, 1.98, 1.68, 1.51, 1.30, 1.22, 1.18, 1.02, 0.98, 0.79. The bands have been correlated with their corresponding vibrational transitions.

[1] Kuiper, Wilson, and Cashman, Astronom. J. **52**, 154 (1947).
[2] Arthur Adel and C. O. Lampland, Ap. J. **93**, 391 (1941).
[3] Arthur Adel and D. M. Dennison, Phys. Rev. **43**, 716 (1933).
[4] Arthur Adel and V. M. Slipher, Phys. Rev. **46**, 902 (1934).

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Bridgman, P. W.—J1
Brown, F. W. and M. A. Greenfield—M2
Brown, V. A. and B. P. Ramsay—C10
Broxon, James B.—A2
Burton, J. A.—H3
Carmichael, H.—A1, G3
Carr, W. J., Jr.—E5
Coltman, J. W. and Fitz-Hugh Marshall—C7
Corben, H. C. and Mulaika Corben—A9
Courant, E. D. and P. R. Wallace—A6
Demers, Pierre—M9
—— and V. Fredette—SP2
Deutsch, Martin—C2
Eisenstein, A.—H2
Estermann, I., A. Foner, and J. A. Randall—E7
Foster, J. S.—I3
Froman, Darol, Louis Rosen, and Bruno Rossi—A3
Goldman, J. E.—E4
Guindon, William G.—A8
Hall, Leonard—S9
Hessaby, M.—S2
de Hoffman, F. and B. T. Feld—A4
Hull, G. F., Jr. and W. Baer—H5
Jacobs, Harold and Armand P. LaRocque—S7
James, Hubert M. and Eugene Guth—S5
Jauch, J. M.—M3
Johnson, V. A. and K. Lark-Horovitz—E10
Kaufman, H. and A. Norman Shaw—S6
Kê, T'ing-Sui—J5
Kinsey, B. B.—A11
Kittel, Charles—E3
Knowles, W.—M7
Koomen, M. J. and R. Tousey—M1
LaPalme, J. and P. Demers—M8
Lawson, A. W.—H8
Marshall, Fitz-Hugh and J. W. Coltman—C8
Marshall, J. S., R. C. Langille, W. M. Palmer, and D. W. Perrie—S11
Matthias, B. T., R. G. Brechenridge, and D. W. Beaumont—H6
Meissner, K. W. and L. G. Mundie—M4
Mendenhall, H. E.—H4
Merchant, M. Eugene—J3
Miller, Arthur E. and Martin Deutsch—C1
Mutter, W. E.—H1
Pepinsky, R. and P. Jarmotz—C12
Placzek, G.—I1
Pound, R. V.—C5
Purcell, E. M.—R2
Ruedy, R.—H9
Saibel, Edward—J4
Scanlon, Wayne and K. Lark-Horovitz—E6
Schaffert, R. M. and C. D. Oughton—M6
Schwarzmann, Gertrude—S1
Seitz, F.—Q1
Shaw, T. M., D. E. Jamison, and J. A. Galvin—S10
Siegert, A. J. F.—S4
Sittner, W. R. and W. S. Huxford—M5
Smith, B. S., H. Carmichael, J. F. Steljes, C. O. Peabody, and D. S. Craig—C6
Smoluchowski, R.—J2, SP1
Stephens, W. E. and Margaret N. Lewis—A10
Stewart, R. W., J. I. Lodge, and J. K. Robertson—S8
Tendam, D. J. and H. L. Bradt—C3
Tisza, L.—H7

**Wallace, P. R.**—A5
**Ward, A. G.**—I2
**Watson, K. M.**—A7
**Welsh, H. L. and M. F. Crawford**—G2
**Williams, H. J.**—E1
**Witmer, Enos E.**—S3
**Wolf, H. E., H. E. Clearman, and W. C. Wineland**—C11
**Worrell, Francis T.**—H10
**Yager, W. A. and R. M. Bozorth**—E2
**Zener, C.**—R1